ON THE DISSIPATION OF TALL CUMULUS CLOUDS

By JEROME NAMIAS

[Massachusetts Institute of Technology, Cambridge, Mass., February 1939.]

Cumulus clouds frequently tower to considerable elevations yet do not develop into cumulo-nimbus. J. Bjerknes [1] has shown that while a distribution of thin cloud columns separated by large clear spaces favors rapidly rising cumuli, there must be a certain minimum cross-section of the cloud masses or else they will be destroyed by wind shear. The manner of dissipation of cumulus-castellatus clouds is frequently difficult to explain on the basis of wind shear alone. Moreover, there are cases in which these clouds rise through an atmosphere in which there is very little wind shear, yet there are well-defined "patterns" in the sequence of forms the clouds undergo in dissipating.

A frequently-observed mode of dissipation is illustrated schematically in figure 1. In 1 (a) and (b) the cloud is developing into the castellatus type. While its top has risen in (c), a thinning process has set in which tends to cut the upper portion of the cloud from the lower. In stage (d) this process is completed and the upper portion becomes separated from the "mother" cloud. After this stage has been reached the upper part is soon destroyed, and normally the lower cloud is gradually dissipated.

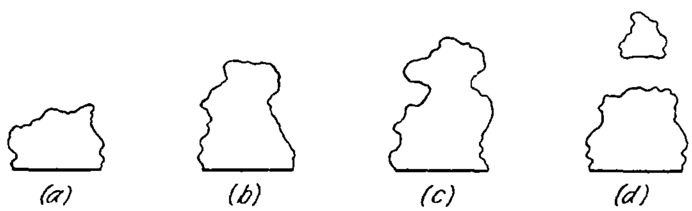

FIGURE 1.—Stages in the disintegration of a cumulus castellatus cloud.

In a recent paper presented at the Kansas City Seminar of the American Meteorological Society, Dr. C. F. Brooks repeated the generally accepted assumption that castellatus clouds may be used as an indication that a steep lapse rate prevails in the layer where the clouds take this columnar shape. The cloud is presumably accelerated in this relatively unstable layer, tending to break away from the cloud in the stable layer below, while upon entering the more stable stratum above is forced to spread out through lateral diffusion, as against a ceiling. While this explanation may hold for vigorously growing clouds, it obviously cannot be true when the cross-section of the rising cloud column at first remains fairly constant or decreases upward, and at a later time becomes thinner at some intermediate level. This latter form of dissipation has been observed frequently by the author and many other students of clouds.

In order to throw some light on this question the author obtained from C. F. Brooks a few excellent photogaphs of a developing, and, later on, disintegrating cumulus castellatus which he took from Blue Hill Observatory on June 14, 1938. One of these photographs, which shows the characteristic thinning out in the mid-portion, is reproduced in figure 2. It was taken at 10:54 a. m. looking west-north-west from the observatory. The radiometeorograph sounding made at 6 a. m. on June 14 at East Boston, shown in figure 3, brings to light several features which may be associated with the cloud photograph. The base of these cumuli were observed by American Airlines pilots flying over the route from Boston to New York. Over Putnam, Conn., the bases were observed at 7,000 feet at 10:48 a. m., and at 6,000 feet at 1:26 p. m. and 2:36 p. m. In view of the fact that Putnam is some distance inland and that NE winds prevailed at Boston from the surface up to high levels, it is probable that the cloud bases were slightly lower nearer Boston. It seems reasonable then to place the cloud base of figure 2 at about 1,800 *m* (6,000 ft.) above sea level. Using this base as a measuring stick, and remembering that the elevation at Blue Hill is 203 *m* above sea level and is about 100 *m* higher than the surrounding terrain, it is possible to find by simple proportion the elevation of the cloud top and other well defined points (using the horizon as a fixed line). By this means, it is found that the top of the cloud is at about 5,200 *m* (535 *mb*). The thin portion of the cloud, so clearly marked in the photograph, is similarly computed to extend from about 3,400 to 3,700 *m* (670 *mb* to 650 *mb*). From these data one may sketch in figure 2 the cloud as it appeared in the picture.[2]

Under these conditions, it is evident that the thin portion of this cloud cannot be ascribed to the more rapid rise in a layer of steep lapse rate, for just in the layer where the cloud is thinnest the lapse rate is most stable—in fact, isothermal.

There are, however, two possible sources of error in this calculation. First, the cloud has been treated as though its base were directly over the horizon, while actually it is between the horizon and the observer. It may be shown, however, that this error cannot be of sufficient magnitude to vitally affect the above results. The other source of error is perhaps of more consequence. If the cloud base is in error by 200 meters or so, the thin portion of the cloud would not be found in the isothermal layer. This is admittedly a weak point in the above method, but the purpose of this illustration is to lend a clue to the problem of the dissipation of the type of cloud with which we are concerned. The author does not consider that the above observations are a proof for the following theory; they merely suggest it, and do not disprove it. It is hoped that this report will stimulate the interest of meteorologists and airplane pilots so that this theory may be definitely proven or disproven through direct observations in the free air.

The above observations indicate a dissipative mechanism based upon the suggestion, originally made by Parr,[3] that lateral mixing is most pronounced in regions of greatest stability. Some cloud columns terminate at the base of stable zones because they have not acquired enough kinetic energy to overcome the stability. When a cloud breaks through the stable layer, it towers above the surrounding clouds, and therefore is a column of moist air surrounded by air which is dry both in its relative and specific humidity. This assumes, of course, that the inversion has dry above moist air, the usual summertime case. In ascending, the cloudy air is mixed with dry air surrounding it, and this process dissipates the cloud. Mixing should be more pronounced in the stable layers than either above or below. In this manner the cloud column assumes forms suggested in figure 1. Finally the intense lateral mixing

[1] V. Bjerknes and others, Physikalische Hydrodynamik, J. Springer, Berlin.

[2] From the picture, some observers might suggest that there is a good anvil projecting toward the observer. However, this possibility is ruled out by the facts that the picture was taken looking WNW and that the upper level winds in this area (as observed by pilot balloons at Boston and Albany) show that a deep northeasterly current persisted up beyond 4,300 *m*.

[3] A. E. Parr, On the Probable Relationship between the Vertical Stability and Lateral Mixing Processes, J. du Conseil, vol. XI, No. 3, 1936.

FIGURE 2.—An example of the beginning of the disintegration of a cumulus castellatus cloud.

in the middle of the cloud column severs the cloud in two, and latent heat of condensation no longer offers a supply of energy to this portion of the rising column. The upper cloudy portion is then acted upon by lateral mixing with the surrounding dry air and is soon destroyed.

A large scale picture of this cutting-off process may be observed when a moist current on the isentropic chart is being depleted of its moisture by dry air on either side, and is thus being cut off from the source of moisture. A striking case of this kind is illustrated in the vertical cross section extending from Sault Ste. Marie, Mich., to Pensacola, Fla., on June 22, 1937 (fig. 4). The pattern of moisture lines in the south is much like that suggested in figure 1c and d. The desiccating process appears to be taking place chiefly between the potential temperature isotherms 310°–315°. It is just in this layer that the vertical stability is greatest. At Pensacola, for example, from 2,430 *m* to 2,600 *m* the potential temperature increases from 310° to 314°—an inversion. Similarly, at Nashville the layer from 2,670 *m* to 3,240 *m* is isothermal (potential temperature from 310° to 315°), and at Montgomery from 1,930 *m* to 2,580 *m* the lapse rate is only 0.3°/100 *m* (potential temperature from 307° to 312°).

The fact that no large inversions of moisture appear in the Pensacola or Nashville accents, in contrast to the Montgomery ascent, shows that the upper level moist tongue is exceptionally narrow and thus presents an ideal opportunity for rapid dissipation by lateral mixing.

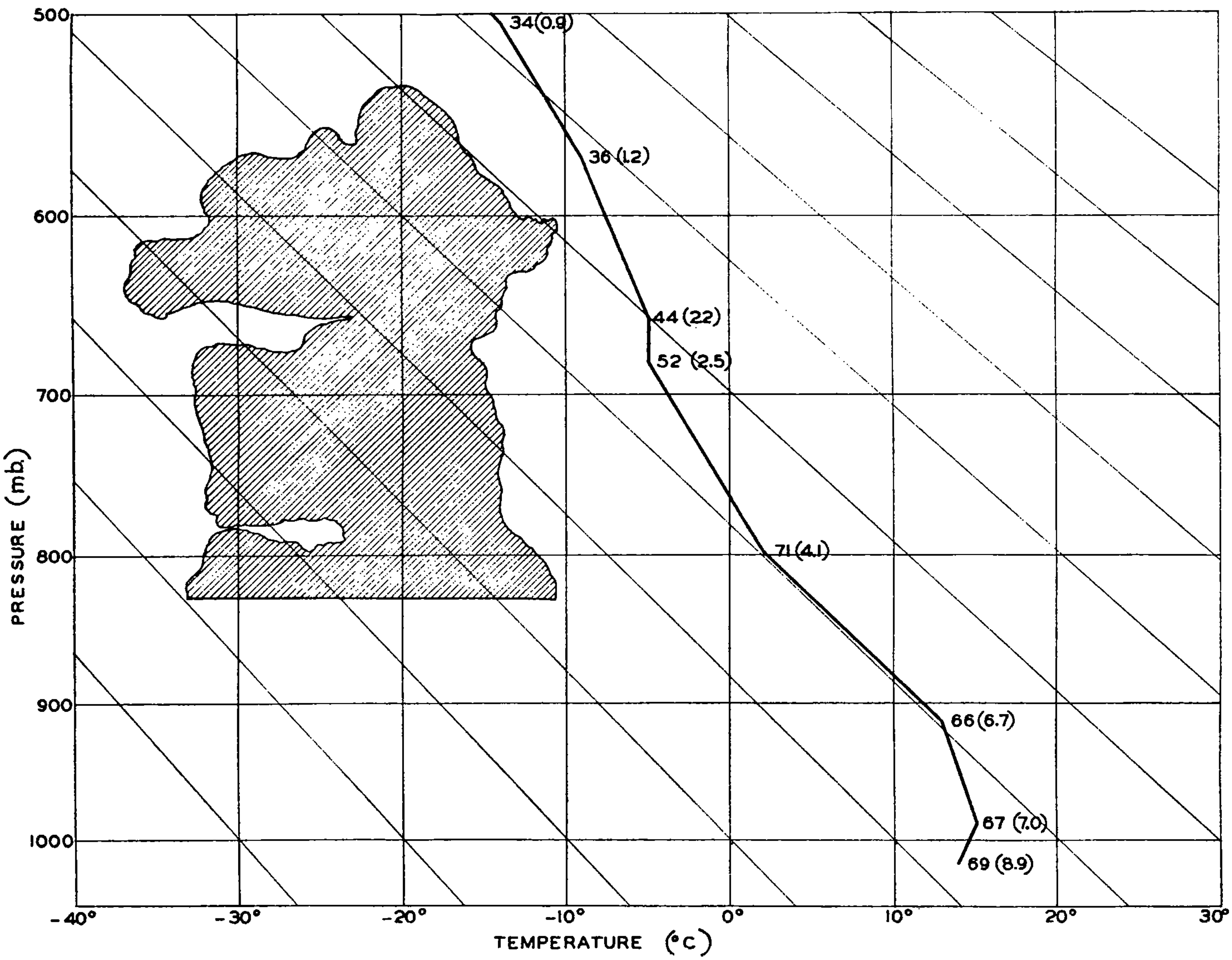

FIGURE 3.—Radiometeorograph sounding at East Boston, Mass., June 14, 1938.

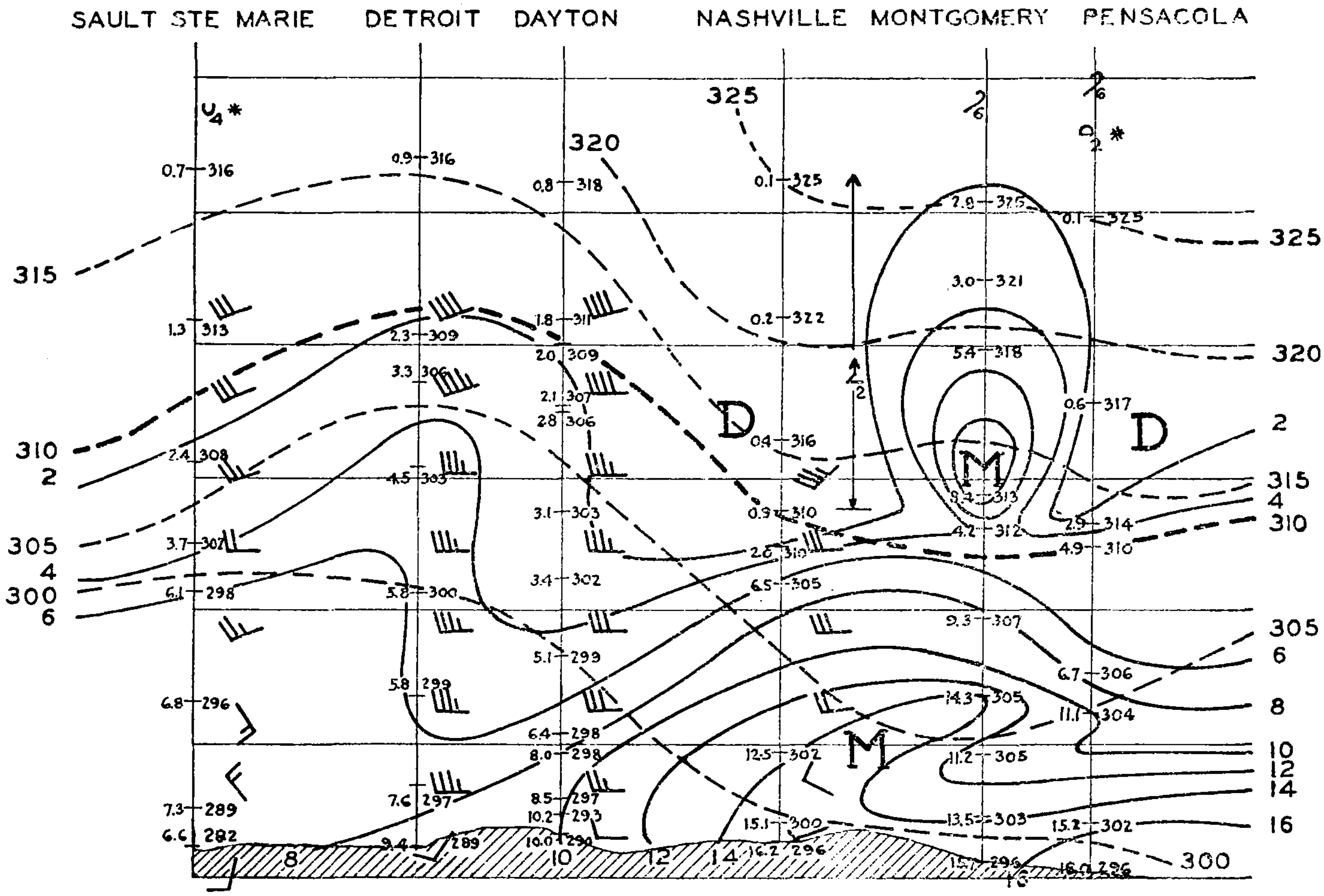

FIGURE 4.—North-south cross section, June 22, 1937.

TROPICAL DISTURBANCE OF AUGUST 1939

By I. R. TANNEHILL

[Marine Division, Weather Bureau, Washington, D. C., September 1939]

There was one well-defined tropical disturbance in August 1939. It originated in Atlantic waters northeast of Puerto Rico on the 8th, moved west-northwestward across Florida and the extreme northeastern Gulf, then progressed very slowly through Alabama, where it was nearly stationary for 3 days, and thereafter moved more rapidly northeastward to southeastern New York where it dissipated on the 20th. On the 30th and 31st, there were indications of a slight disturbance over the extreme eastern Caribbean Sea but no further evidences of it were reported after the end of the month.

August 8–20.—The first definite evidence of this disturbance was on August 8. During the day several ships in the general vicinity of 22° N., 66° W. reported easterly winds of force 6 and rough seas. The disturbance moved west-northwestward during the next 3 days, crossing the Bahamas late on the 10th and early on the 11th. The center reached the east coast of Florida in the late afternoon of the 11th. Its progressive movement had increased gradually from about 10 miles an hour on the 8th to approximately 15 miles an hour on the 10th and 11th. Ship reports do not indicate that it was of more than moderate intensity in the Atlantic. The highest wind noted on shipboard was force 10. The American steamship *Pan Amoco* reported by radio at 7 p. m., August 11, when located at 27.6° N., 79.6° W., wind E., force 10, barometer 1,005 millibars (29.68 inches).

On the east coast the lowest pressure and highest wind were recorded at Fort Pierce, 991.2 millibars (29.27 inches) and 54 miles per hour.

In crossing Florida the rate of progression increased to about 18 miles per hour, while the intensity of the disturbance did not change materially. The center passed very close to Lakeland and Tarpon Springs and moved to the extreme northeastern Gulf on the 12th. At the Tampa Airport the highest wind was 62, south-southwest at 4:30 a. m. on the 12th, the lowest pressure 998.6 millibars (29.49 inches).

Late in the afternoon of the 12th the disturbance entered western Florida near Apalachicola, the center passing over Port St. Joe, at 6 p. m., eastern standard time. At Apalachicola, lowest pressure was 990.9 millibars (29.26 inches) at 6 p. m., the highest wind 52, northeast at 4:18 p. m. A lull followed, with velocities averaging 26 miles per hour, after which the wind increased to 46 south at 6:45 p. m. The storm center also passed over Panama City and St. Andrews, the lowest reported pressure at the latter place being 988.5 millibars (29.19 inches) at 9:10 p. m.

The following comments on damage by the storm are taken from the report of Forecaster Norton at Jacksonville:

In peninsular Florida the damage by this storm was minor in character, as would be expected for a storm of only moderate